NEW OCTOPUS SPECIES FROM QUEENSLAND

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Three new octopus species are added to the growing list of Australian octopods. All are known solely on the basis of trawl material from habitats not easily surveyed using standard diving techniques. *Octopus harpedon* sp. nov. attains arm spans in excess of 2m. It occurs in shallow muddy waters in the Gulf of Carpentaria. *Octopus bulbus* sp. nov. is also a long-armed species, which possesses a swollen bulbous ligula and a skin ridge around the lateral mantle. *Octopus micros* sp. nov. is tiny (mature at <25mm mantle length), the first pygmy species to be reported with a lateral mantle ridge. The latter 2 species occur on the continental shelf off southern Queensland in water depths of 18-195m and 166-195m, respectively. The phylogenetic affinities and potential life styles of these octopuses are discussed in light of their morphological attributes. ❐ *Octopus, taxonomy, morphology, Queensland, Cephalopoda.*

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Research into benthic octopuses of Australia and the Indo-West Pacific region over the past decade has revealed more than 70 new species of octopus in Australian waters (Stranks, 1988a-b, 1990; Norman, 1992, 1993a-d, 1998; Stranks & Norman, 1993; Norman et al., 1997; Norman, unpubl. data), the bulk of which await formal description. Within this fauna are 3 distinctive and very different octopus species from Queensland waters.

The 'Spaghetti Octopus', *Octopus harpedon* sp. nov. is reported from the shallow waters of the Gulf of Carpentaria. This octopus has extremely elongate arms (up to 10 times mantle length) and would attain arm spans of >2m when foraging over its soft sediment habitat.

The other two species were collected from continental shelf waters (>150m) off the south coast of Queensland. The 'Swell-Club Octopus', *Octopus bulbus* sp. nov., is also long-armed (arms to 5 times mantle length) with a distinctive swollen ligula. Arm spans of live animals would be up to 50cm. This species possesses a distinctive lateral mantle ridge.

The 'Pygmy Keeled Octopus', *Octopus micros* sp. nov., is tiny with an arm span of <12cm and a weight of <6g. It is the first pygmy species to be reported with a lateral mantle ridge.

There are few specimens available for these species, all originating from trawl surveys. None of these new species have been observed live. Based on the available material, the taxonomic affinities and potential habits of these little-known creatures are discussed.

SYSTEMATICS

FAMILY OCTOPODIDAE

Octopus harpedon sp. nov.
(Figs 1-2, 9A-B, 10A-C)

MATERIAL. HOLOTYPE: 1♂,: 56.9mm ML, AMC30411, Albatross Bay, near Weipa, Gulf of Carpentaria. PARATYPE: 1♀, 96.1mm ML, AM C304112, SE Gulf of Carpentaria, 16°27'40"S, 141°15'25"E, 2m.

TYPE LOCALITY. Albatross Bay, near Weipa, Gulf of Carpentaria, Australia

ETYMOLOGY. Greek *harpedon*, thread-like; referring to elongate, thread-like arms."Spaghetti Octopus" is proposed as a common name.

DIAGNOSIS. Moderate-sized (ML to 96mm) with spindle-shaped mantle and bulbous eyes. Arms greatly elongate, up to 9 times mantle length. Second arm pair appears longest (arm formula approximately 2>1=3>4). Webs very shallow, less than 5% of arm length. Approximately 270 suckers on intact arms of mature animals. Third right arm of male hectocotylised, very short (only 20% of length of opposite arm) and bearing 49 suckers. 10-11 gill lamellae per demibranch. Eggs large-type. Skin largely unpigmented, dark blue subdermal pigment around eyes produces 'bruised' appearance. Skin smooth. Lateral ridge absent.

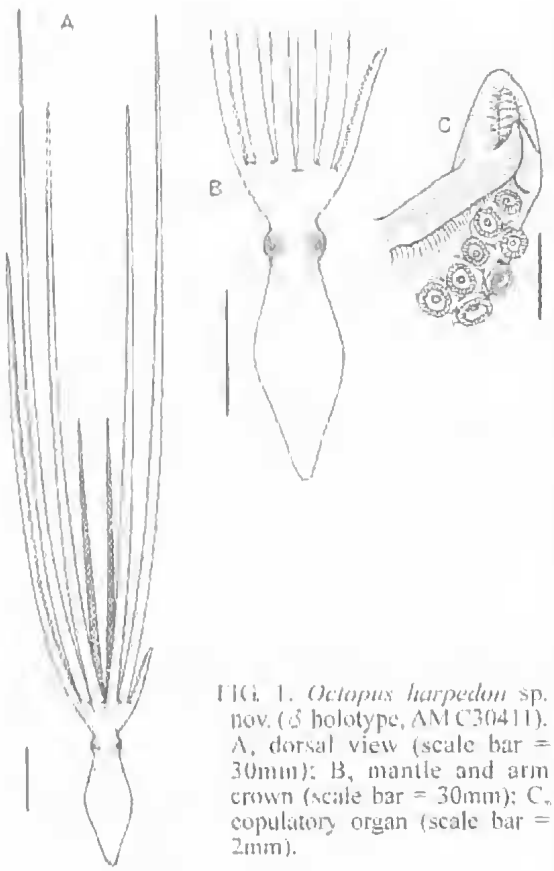


FIG. 1. *Octopus harpedon* sp. nov. (♂ holotype, AM C30411). A, dorsal view (scale bar = 30mm); B, mantle and arm crown (scale bar = 30mm); C, copulatory organ (scale bar = 2mm).

DESCRIPTION. Counts and measurements were taken off a single specimen of each sex, the only known specimens of this distinctive species. Raw morphological data are presented in Table 1.

Moderate sized species with extremely long arms (Figs 1A-B, 9A-B); mantle lengths (ML) 56.9mm for male holotype and 96.1mm for female paratype. Total length of ♂ 394mm and ♀ 997mm; weight to at least 104g. Mantle elongate to spindle-shaped, much longer than wide (♂: width 35.1% of ML; ♀: width 24.9% of ML), mantle walls thin to moderately muscular. Head narrower than mantle (♂: 26.4% of ML, 75.0% of mantle width; ♀: 15.8% of ML, 63.6% of mantle width). Eyes moderate to small, only slightly pronounced. Stylets absent. Mantle aperture of moderate width, approximately half circumference of body at level of opening. Funnel narrow and elongate, approximately 50% of mantle length (♂: 51.5% of ML; ♀: 47.9% of ML), free portion short, approximately one third of funnel length (♂: 23.9% of funnel length; ♀: 33.5% of funnel length). Funnel organ not evident in either specimen.

Arms extremely long, longest >5 times mantle length (♂: 5.9 × ML; ♀: 9.1 × ML). Arms narrow relative to mantle length (♂: 9.3% of ML; ♀ [ex frozen]: 5.9% of ML), widest midway along arm, roughly square in cross section. Arms unequal in length, ventral pair distinctly shortest, second pair appears longest (arm formula: ♂: ~2>1>3>4, ♀: ~2>1=3>4). Suckers in two rows and of moderate size (♂: 7.0% of ML, ♀: 5.0% of ML), slightly elevated with only slight flare. No enlarged suckers evident in either sex. Approximately 280 suckers on intact arms of mature animals (♂: 272 suckers on left third arm; ♀: 291 suckers on left third arm). Webs tiny, shortest relative to arm length reported for any octopus (♂: deepest web 3.9% of longest arm; ♀: deepest web 2.4% of longest arm). Web sectors approximately equal in length. Web margins along arms absent.

Third right arm of males hectocotylised. Modified arm very short, less than mantle length (79.1% of ML), and around 20% of length of opposite arm (20.4% of opposite arm). Ligula moderate-size (7.3% of arm length, 5.8% of mantle length), in the form of a small thick-lipped spoon with transverse creases across the open ligula groove (Fig. 1C). Calamus distinct and sharp, approximately one half of ligula length (54.6% of ligula). Spermatophore groove well developed and wide with fine transverse creases. Spermatophore guide distinct with a ridge of elevated square papillae. Forty-nine suckers on hectocotylised arm of single male.

Gills with 10-11 lamellae on both inner and outer demibranchs, plus terminal lamella.

Digestive tract (Fig. 2A). Anterior salivary glands extend along approximately one third of buccal mass from posterior margin on dorsal surface. Posterior salivary glands elongate and of moderate length (similar in length to buccal mass, approximately 30% of digestive gland length). Crop diverticulum present, long and narrow. Stomach bipartite. Caecum coiled in approximately 1.5 whorls with distinct striations. Digestive gland long and narrow, not bound in an iridescent membrane. Narrow intestine reflexed several times in proximal third. Ink sac well developed, embedded in ventral surface of digestive gland. Anal flaps absent. Upper beak with a hooked rostrum, concave and notched on the cutting edge, and a small hood (Fig. 2B). Lower beak with narrow short rostrum, hood

narrow, widely spread wings and slightly flared lateral walls (Fig. 2C-D). Radula with 7 teeth and 2 marginal plates in each transverse row (Fig. 10A-C). Rhachidian tooth with 2-3 lateral cusps, on each side of moderately long medial cone (Fig. 10A). Lateral cusps in asymmetrical seriation, migrating from lateral to medial position over 7-8 transverse rows (Fig. 10B). First lateral teeth unicuspidate with cusp towards lateral edge. Second lateral teeth unicuspidate and long with curved base. Lateral marginal teeth straight. Marginal plates oblong and plain (Fig. 10C).

Male genital tract not fully formed. Submature terminal organ ('penis') T-shaped with diverticulum slightly longer than distal portion.

Female genital tract not fully formed but eggs in tiny ovary already large and low in numbers (<100). This species would produce large eggs and the young are likely to be benthic on hatching. Oviducts elongate, opening posterior to the narrow short septum.

Colour in life unknown. Preserved specimens uniformly cream (♀) and pink (♂) with dark subdermal pigmentation around the eyes of both specimens giving a 'bruised' appearance (Fig. 1B). Dorsal White Spots (*sensu* Packard & Sanders, 1971) absent. Skin smooth. Lateral mantle ridge absent. Nothing is known of the behaviour and general biology. The short hectocotylised arm of the ♂ suggests mounted copulation in this species as opposed to other octopus species where a long hectocotylised arm enables copulation from a distance (as found in other long-armed species such as *O. aculeatus*, Norman & Finn, 2001). Numerous spiral parasites were present along sections of the digestive tract, particularly adjacent to the crop and intestine.

TAXONOMIC REMARKS. Only one other Australian octopus has arms of comparable relative length. *Ameloctopus litoralis* Norman, 1992 is an intertidal, smaller species (ML to 30mm) with arms up to 10 times the mantle length. It is distinguished from *O. harpedon* in that it has a much lower gill count (5-6 versus 10-11 lamellae per demibranch), a linear terminal organ which lacks a diverticulum, distinctive bands along the arms (compared with little pigmentation in *O. harpedon*), and it lacks an ink sac.

An undescribed octopus from Hong Kong, China and Taiwan also shows similarities to this new species, sharing similar arm lengths and gill

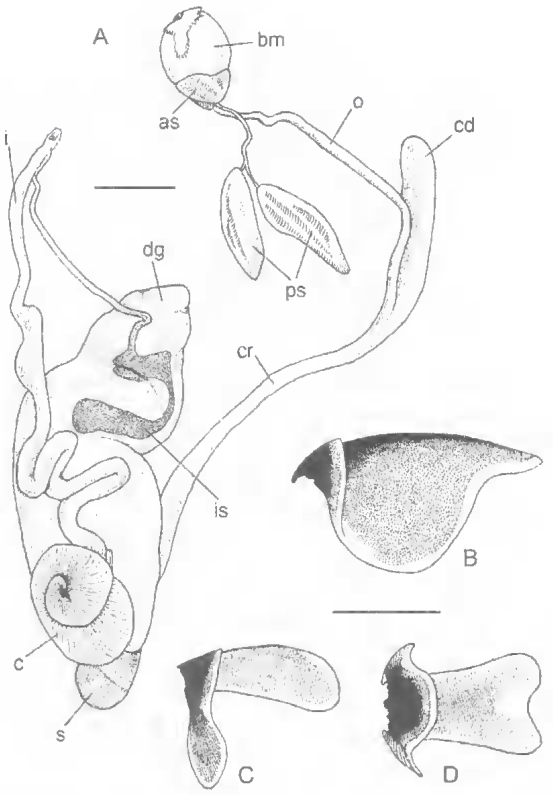


FIG. 2. *Octopus harpedon* sp. nov. A, digestive tract (♀, AM C304112): as = anterior salivary glands, bm = buccal mass, c = caecum, cd = crop diverticulum, cr = crop, dg = digestive gland, i = intestine, is = ink sac, o = oesophagus, ps = posterior salivary gland, s = stomach (scale bar = 10mm). B-D, beaks (♂ holotype, AM C30411) (scale bar = 3mm); B, upper beak, lateral view; C, lower beak, lateral view; D, lower beak, ventral view.

counts. This Asian taxon has been treated under a number of names by various authors: *Octopus* sp. B. Voss & Williamson, 1972; *Octopus fusiformis* (non Brock, 1887) in Dong, 1987; *Octopus* sp. 1 Norman & Hochberg, 1994. It can be distinguished from *O. harpedon* on the basis of differences in arm formula (1>2>3>4 versus second pair longest in *O. harpedon*) and hectocotylised arm length (~50% versus 20% of opposite arm length in *O. harpedon*). Additional mature material of both taxa is required to further resolve the relationship between these octopuses.

As for higher taxonomic affinities, *O. harpedon* shares a number of characters with poorly-known *Euaxoctopus* Voss, 1971. *Euaxoctopus* contains 2 quite different species from

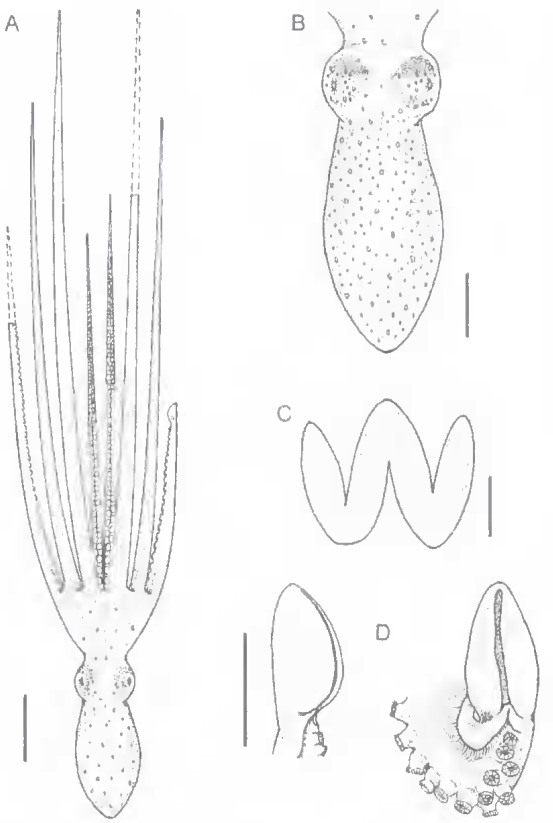


FIG. 3. *Octopus bulbus* sp. nov. (♂ holotype, MV F87067); A, dorsal view (scale bar = 20mm); A, mantle (scale bar = 10mm); B, funnel organ (scale bar = 5mm); C, copulatory organ (scale bar = 5mm).

either side of the Panama Isthmus. *E. pillsburyae* Voss, 1971 and *E. panamensis* Voss, 1975 share long arms of which the second pair are longest, shallow webs, paired semi-circular ocelli on the mantle, a large crop, a rhachidian tooth of the radula with 1-2 lateral cusps on each side (typically 1), a blunt linear terminal organ with a diverticulum longer than the distal free portion, and distinctive spermatophores with flattened coils in the oral tip. The two member species differ in that *E. panamensis* has a hectocotylised left arm, a gill count of 11-13 lamellae, and a VV-shaped funnel organ, while *E. pillsburyae* has the right third arm hectocotylised, a gill count of 7, and a W-shaped funnel organ. *Octopus harpedon* shares the same arm formula (second pair longest) and blunt linear terminal organ with a diverticulum longer than the distal free portion. It differs in lacking the semicircular ocelli on the mantle and possesses a radula with a higher number of lateral cusps on the rhachidian tooth (2-3 per side). In the absence of mature material of *O. harpedon* spermatophores can not be compared. The disparate composition of *Euaxoctopus* and the absence of replicate well-preserved material for both this genus and *O. harpedon* prevent further resolution of their affinities. Based on available material, I place this species in *Octopus*.

Octopus harpedon shares several morphological characters with the '*Octopus macropus* group' (Norman, 1993a). This group is characterised by an arm formula of 1>2>3>4, high gill counts (10+ lamellae per demibranch) and a rhachidian tooth of the radula with 2-3 cusps on each side of the medial tooth, migrating from medial to lateral positions over 7-8 transverse rows. The radula and gill count of *O. harpedon* match those of the *Octopus macropus* group but arm length, arm formula and ligula shape differ.

Until more material becomes available (including fresh tissue for molecular analyses), the higher affinities of this distinctive octopus remain unknown.

Octopus bulbus sp. nov.
(Figs 3-5, 9C, 10D-F)

MATERIAL. HOLOTYPE: 1♂: 41.1mm ML, MV F87067, east of Mooloolaba, 16-20 miles north of Cape Moreton, southern Queensland, 90-106fm (166-195m), trawl, FV 'Debie-Marie', 11-13 Aug 1981, coll. G. Smith, Queensland Fisheries. PARATYPES: 1♂: 53.0mm ML, MV F87068, East of Noosa, southern Queensland, 63fm (116 m), trawl, FV 'Rhonda Lane', 12 Dec 1980, coll. M. Potter, Queensland Fisheries; 1♀: 49.2mm ML, MV F87069, off Mooloolaba, southern Queensland, 10fm (18.4m), trawl, 1500-1600hrs, FV 'Rhonda Lane', 14 Dec 1980, coll. M. Potter, Queensland Fisheries.

TYPE LOCALITY. East of Mooloolaba, southern Queensland, Australia.

ETYMOLOGY. Latin *bulbus*, fleshy swelling; referring to the distinctive swollen ligula. 'Bulb-tip Octopus' is proposed as a common name.

DIAGNOSIS. Small (ML to 50mm) with relatively long arms, approximately 5 times mantle length. Dorsal arms longest, receding to ventral arm pair (arm formula I>2>3>4). 7-8 gill lamellae per demibranch. Approximately 200 suckers on intact arms. Third right arm of ♂♂ hectocotylised, bearing approximately 90 suckers. Posterior salivary glands large and elongate (almost twice length of buccal mass, approximately 60% of digestive gland length). Ligula large (8% of hectocotylised arm length)

with greatly swollen lips to the ligula groove. Spermatophores thick and short, approximately half mantle length. Dorsal mantle and arm crown sculptured with scattered pink-red raised patches. Lateral ridge present.

DESCRIPTION. Counts and measurements were taken off the only known specimens, 2 mature ♂♂ and a submature ♀. Morphological data are presented in Table 1.

Moderate-sized elongate (Fig. 3A); mantle length to around 50mm (♂: to 53.0mm ML, ♀: 49.2mm ML). Total length to 341mm; weight to at least 47g. Mantle elongate to spindle-shaped, much longer than wide (width 53.5% of ML in holotype, other material distorted from freezing), mantle walls moderately muscular. Head approximately same width as mantle (53.3% of ML, 99.5% of mantle width in holotype, other material distorted from freezing). Eyes large and pronounced. Stylets absent. Mantle aperture of moderate width, approximately half circumference of body at level of opening. Funnel broad-based, approximately one half of mantle length (41.8-62.2% of ML), free portion elongate, 32.1-56.0% of funnel length. Funnel organ W-shaped with broad limbs (Fig. 3A). Outer limbs slightly shorter in length than median limbs (outer limbs 86.4% of median limbs in holotype). Funnel organ occupies approximately two thirds of funnel length (59.8% of funnel length).

Arms long, approximately 5 times mantle length (longest 4.9-5.6 × ML). Arms of moderate width relative to mantle length (13.9% of ML), widest at one third of arm length from base then tapering evenly to tip, roughly square in cross section. Arms unequal in length, dorsal pair longest (arm formula: 1>2>3>4). Suckers in 2 rows and of moderate size (6.7-9.8% of ML), slightly elevated with low flare and a deep cup. No enlarged suckers evident in either sex. Approximately 190 suckers on intact arms of mature animals (196 suckers on fourth right arm of holotype). Webs shallow and thin (deepest web 10.9-11.5% of longest arm in intact specimens). Dorsal and lateral web sectors approximately equal in length, ventral webs shallower (web formula A=B=C>D>E). Web margins extend along both dorsal and ventral aboral edges of arms for less than one third of the arm length.

Third right arm of ♂♂ hectocotylised. Modified arm relatively short, almost half as long as normal arms (2.0-2.5 × ML, 56.3% of opposite arm). Ligula large (8.0-8.6% of hectocotylised arm length, 16.1-21.9% of mantle length), in the form of an elongate oval with a deep closed groove (Fig. 3C-D). Calamus small and sharp, <20% of ligula length (17.2-18.2% of ligula). Spermatophore groove well developed, of moderate width with fine transverse creases. Spermatophore guide not obvious. Approximately 90 suckers on hectocotylised arm (91, 94).

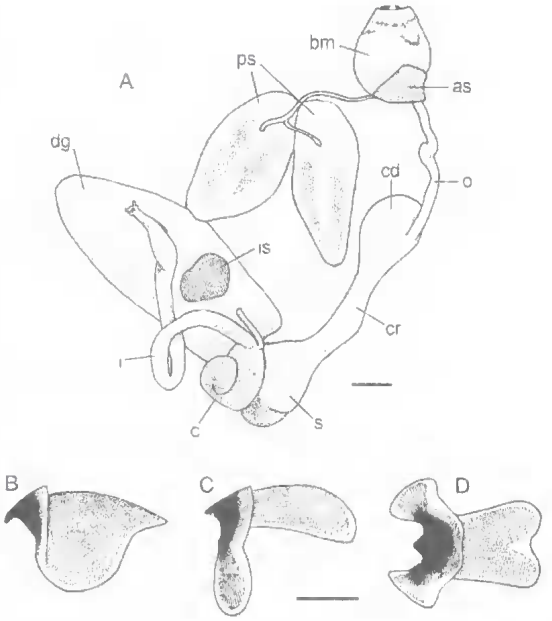


FIG. 4. *Octopus bulbus* sp. nov. digestive system (♀ paratype, MV F87068); A, digestive tract: symbols as in Fig. 2 (scale bar = 5mm). B-D, beaks; B, upper beak, lateral view; C, lower beak, lateral view; D, lower beak, ventral view (scale bar = 3mm).

Gills with 7-8 lamellae on both inner and outer demibranchs, plus terminal lamella.

Digestive tract (Fig. 4A). Anterior salivary glands extend along approximately one third of buccal mass from posterior margin on dorsal surface. Posterior salivary glands large and elongate (almost twice length of buccal mass, approximately 60% of digestive gland length). Crop diverticulum present, moderately small. Stomach bipartite. Caecum coiled in 1.5 whorls, with distinct striations. Digestive gland approximately ovoid. Muscular intestine reflexed approximately one third along length from proximal end. Ink sac wel-developed, embedded in ventral surface of digestive gland. Anal flaps present, small. Upper beak with a hooked rostrum, concave on cutting edge, and moderate

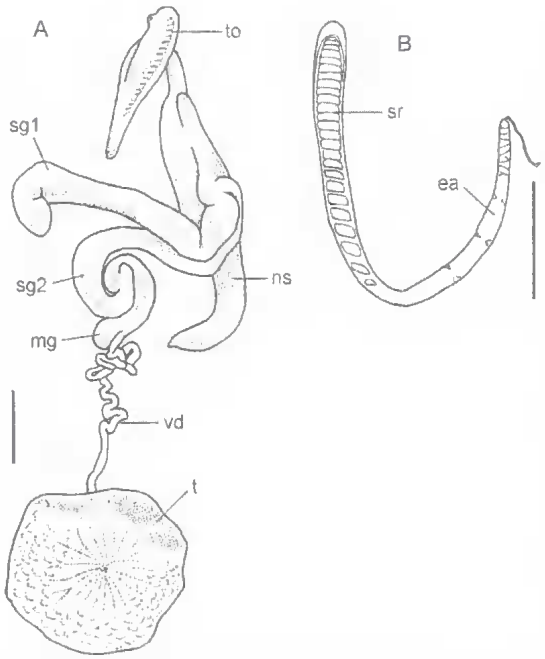


FIG. 5. *Octopus bulbus* sp. nov. reproductive system (♂ holotype, MV F87067). A, reproductive tract: mg = mucilagenous gland, ns = Needham's sac, sg1 = spermatophoric gland, sg2 = accessory spermatophoric gland, t = testis, to = terminal organ ('penis'), vd = vas deferens (scale bar = 5mm); B, spermatophore: ea = ejaculatory apparatus; sr = sperm reservoir (scale bar = 5mm).

hood (Fig. 4B). Lower beak with pointed rostrum, narrow hood, widely-spread wings and slightly flared lateral walls (Fig. 4C-D). Radula with 7 teeth and 2 marginal plates in each transverse row (Fig. 10D-F). Rhachidian tooth with 2-3 lateral cusps, typically 2, on each side of long thin medial cone (Fig. 10D). Lateral cusps in asymmetrical seriation, migrating from lateral to medial position over 7-8 transverse rows (Fig. 10E). First lateral teeth unicuspidate with cusp towards lateral edge. Second lateral teeth unicuspidate with curved base. Lateral marginal teeth robust and curved. Marginal plates oblong and plain (Fig. 10F).

Male genitalia (Fig. 5A). Terminal organ ('penis') robust and roughly linear with a diverticulum of similar length as the free distal portion. Distorted by spermatophore in holotype (Fig. 5A). Spermatophores (Fig. 5B) short, around half mantle length (22mm, 53.5% of ML in holotype), and thick (1.1mm, 2.7% of ML), produced in low numbers (1 in spermatophore storage sac, 1 in terminal organ in holotype). Oral cap contains thick coils of ejaculatory apparatus and bears a thick cap thread. Sperm reservoir long, 54% of spermatophore length in holotype, containing a thick sperm cord forming coiled in approximately 24 regular whorl. Only ♀ specimen is submature. Submature eggs large-type and produced in low numbers (<100). The large eggs indicate that juveniles are likely to adopt a benthic habit on hatching.

Colour in life unknown. Preserved specimens cream with pink-red raised patches scattered on dorsal mantle and upper arm crown. Pink low small papillae on dorsal skin between larger patches. Regular fine papillae on ventral mantle. Dark blue subdermal pigmentation around eyes with superficial red brown chromatophores (Figs 3A, 9C). Webs cream in contrast to pink brown arms. Dorsal White Spots (*sensu* Packard & Sanders, 1971) absent. Scattering of low papillae pronounced around eyes. Lateral mantle ridge present. Small regular low papillae on ventral mantle within lateral ridges.

Nothing known of behaviour or general biology.

DISTRIBUTION. *Octopus bulbus* sp. nov. is known from only 3 specimens, collected off southern Queensland, in 18-195m.

TAXONOMIC REMARKS. *Octopus bulbus* shares a number of attributes with *O. australis* Stranks & Norman, 1993, also found in shallower waters in the region. Both species share a lateral ridge, bulbous ligula and similar gill counts (7-8 in *O. bulbus* versus 7-9 in *O. australis*). However, these taxa have very different floorplans and reproductive characters, suggesting separate evolutionary origins. *Octopus bulbus* has arm and web formulae in which dorsal arms and webs are longer/deeper (AF 1>2>3>4, WF A=B=C >D>E), whereas *O. australis* has longer/deeper lateral arms and webs (AF 3>2>4>1, WF typically D>C>B>E>A). *Octopus bulbus* also has longer arms (4.9-5.6 versus 2.7-4.3 × ML), shallower webs (10-12% versus 20-30% of longest arm), a proportionally shorter hectocotylised arm (56% versus 66-86% length of opposite arm) with a higher sucker count (91, 94 versus 62-77), absence of enlarged suckers in mature ♂♂ (suckers 6.7-9.8% versus 12.6-15.3% ML), and spermatophores with far fewer sperm cord whorls (24 versus >60).

The longer dorsal arms (arm formula 1>2>3>4) and a multicuspid radula (2-3 cusps on each side of the rhachidian tooth) are similar to

those of the '*Octopus macropus* group' (Norman, 1993a). However, the gill count of 7-8 is lower than any previously reported for the group all of which possess 10-15 lamellae per demibranch. Until more material becomes available (including fresh tissue for molecular analyses), the higher affinities remain unknown.

Octopus micros sp. nov.
(Figs 6-8, 9D, 10G-H)

MATERIAL. HOLOTYPE: 1♂: 18.8mm ML, MV F87070, east of Mooloolaba, 16-20 miles north of Cape Moreton, southern Queensland, 90-106fm (166-195m), trawl, FV 'Debie-Marie', 11-13 Aug 1981, coll. G. Smith, Queensland Fisheries. Paratypes: 1♂: 20.7mm ML, 1♀: 24.5mm ML, MV F78815, off Mooloolaba, southern Queensland, trawl, FV 'Debie-Marie', 11-13 Aug 1981, coll. G. Smith, Queensland Fisheries (no depth data).

TYPE LOCALITY. East of Mooloolaba, southern Queensland.

ETYMOLOGY. Greek *mikros*, small referring to its small size. 'Pygmy Keeled Octopus' is proposed as a common name.

DIAGNOSIS. Small species (ML to 25mm) with short arms (2-3 × ML) of approximately equal length, dorsal pair slightly shorter. Lateral webs slightly deeper than dorsal web. Enlarged suckers absent in both sexes. Gills with 6 lamellae per demibranch. Hectocotylised arm (third right) approximately 80% of length of opposite arm. Ligula of moderate size (~6% of arm length) with open groove. 85-93 suckers on hectocotylised arm. Terminal organ (penis) robust and linear with simple rounded diverticulum. Spermatophores approximately equal in length with mantle. Lateral mantle ridge present.

DESCRIPTION. Counts and measurements are from the known specimens, 2 mature ♂♂ and a submature ♀ (Table 1).

Robust pygmy species (Fig. 6A); mantle length to 20.7mm for ♂♂, 24.5mm for ♀. Length to 91mm; weight to at least 5.8g. Mantle ovoid to spherical, slightly longer than wide (width 63.3-76.1% of ML), mantle walls moderately muscular. Head width similar to mantle (56.3-76.1% of ML, 89.0-100% of mantle width). Eyes moderate to large and moderately pronounced. Stylets present (Fig. 6B), non-mineralised, 4.4mm in holotype, 23.4% of ML. Mantle aperture of moderate width, approximately half circumference of body at level of opening. Funnel broad and short, approximately one third of mantle length (33.0-41.1% of ML), free portion 44.7-63.5% of funnel length. Funnel organ W-shaped with broad limbs (Fig. 6C). Outer limbs similar in length to median limbs (outer limbs 92.9-105.2% of median limbs). Funnel organ occupies approximately two thirds of funnel length (60.4-67.7% of funnel length).

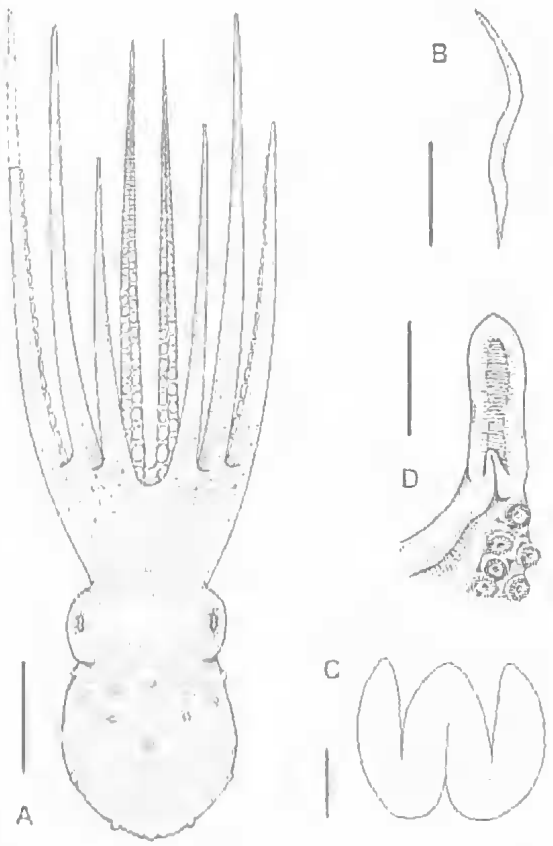


FIG. 6. *Octopus micros* sp. nov. (♂ holotype, MV F87070). A, dorsal view; B, stylet (scale bar = 2mm). C, funnel organ (♀ paratype, MV F78815) (scale bar = 3mm). D, copulatory organ (♂ paratype, MV F78815) (scale bar = 2mm).

Arms of moderate length, longest approximately 2.5 times mantle length (2.3-2.7 × ML). Arms moderately robust relative to mantle length (16.9-19.7% of ML) tapering evenly to fine tips, rounded in cross section. Arms roughly equal in length, dorsal pair slightly shorter (arm formula typically 4=3=2>1). Suckers in 2 rows and of moderate size (9.8-11.7% of ML), slightly elevated with moderate flare and a thin rim. Enlarged suckers absent in both sexes. Approximately 150 suckers on intact arms of mature animals. Webs of moderate depth (deepest web 22.3-27.1% of

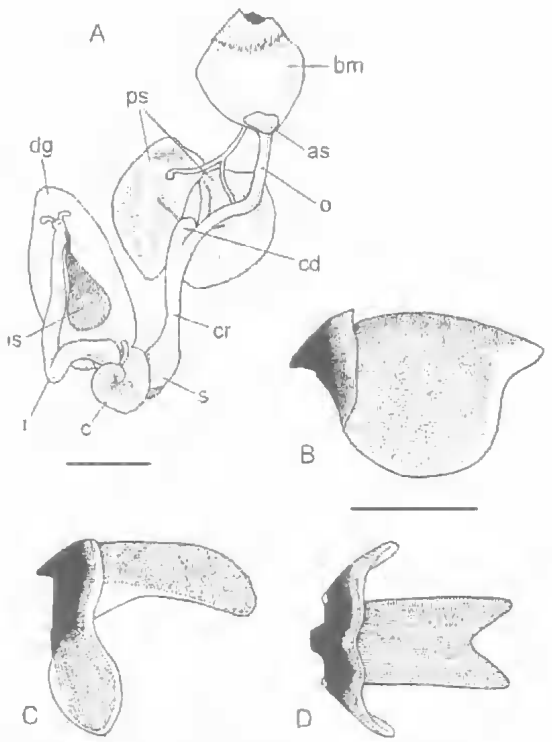


FIG. 7. *Octopus micros* sp. nov. digestive system (♀ paratype, MV F78815); A, digestive tract, symbols as in Fig. 2 (scale bar = 5mm). B-D, beaks (scale bar = 3mm); B, upper beak, lateral view; C, lower beak, lateral view; D, lower beak, ventral view.

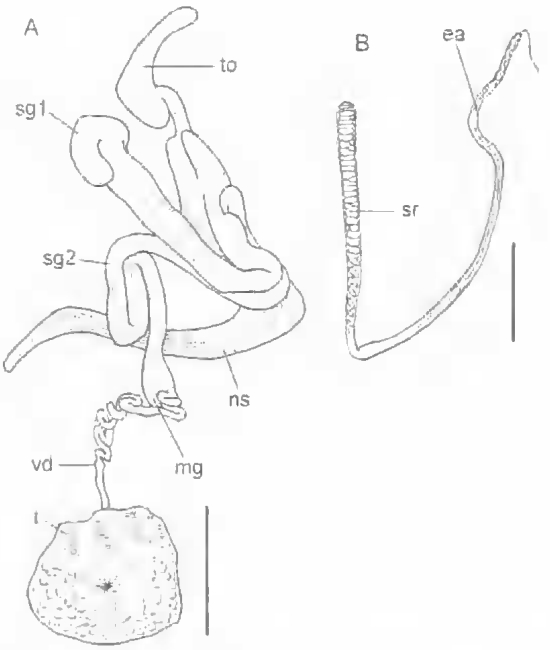


FIG. 8. *Octopus micros* sp. nov. reproductive system (♂ holotype, MV F87070), symbols as in Fig. 5; A, reproductive tract (scale bar = 5mm); B, spermatophore (scale bar = 3mm).

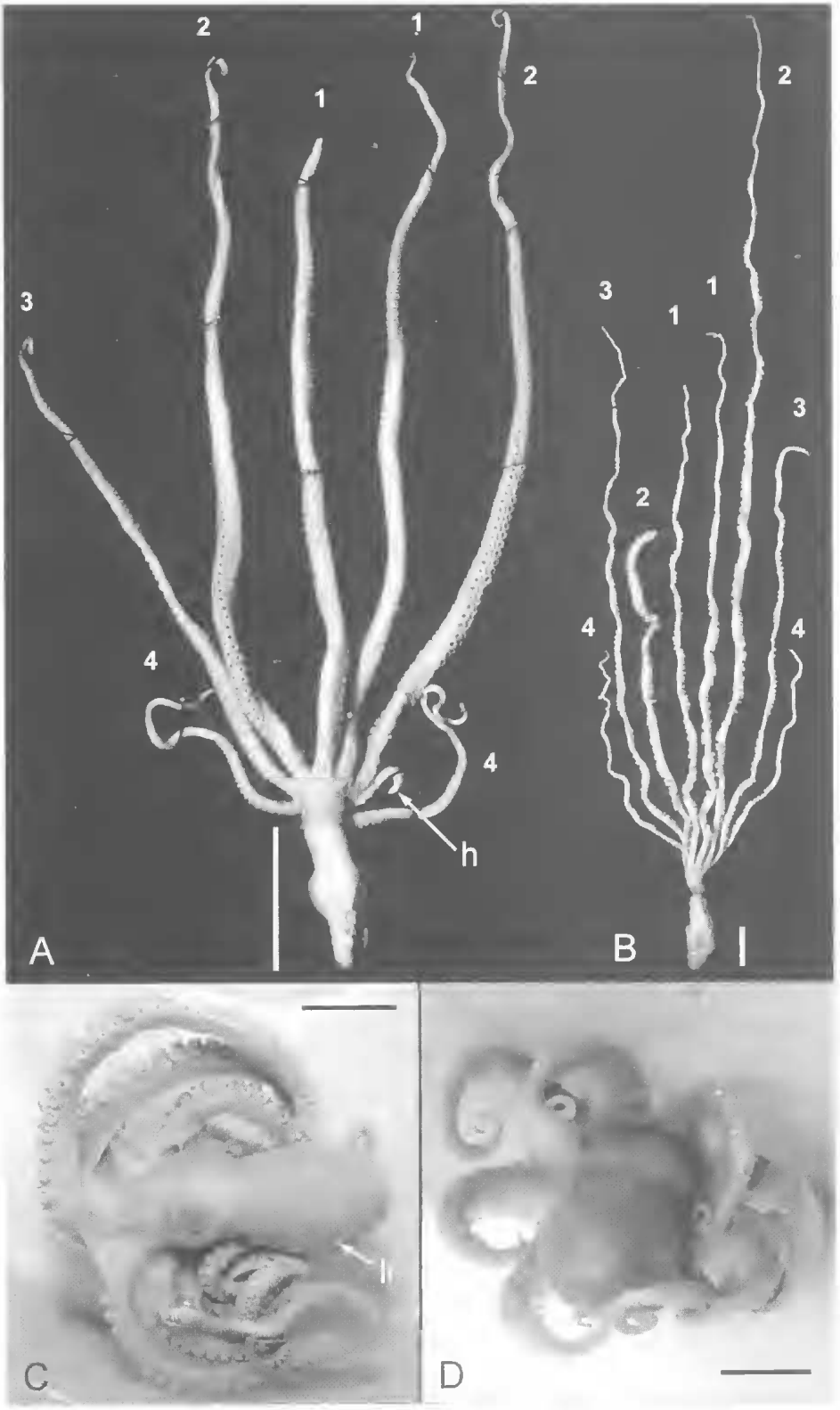
longest arm). Lateral web sectors slightly deeper than other webs (web formula B=C=D>E>A). Web margins extend as thin ridges for a short distance along ventral edge of arms.

Third right arm of ♂♂ hectocotylised. Modified arm relatively long, almost as long as normal arms (2.0-2.2 × ML, 86% of opposite arm in intact male). Ligula moderate-size (6.4% of arm length, 14.4% of mantle length), in the form of an elongate pointed leaf with fine transverse creases across the open ligula groove (Fig. 6D). Calamus distinct and sharp, approximately one half of ligula length (44.4% of ligula). Spermatophore groove well-developed and wide with fine transverse creases. Spermatophore guide shallow with no obvious papillae. 85-93 suckers on hectocotylised arm.

Gills with 6 lamellae on both inner and outer demibranchs, plus terminal lamella.

Digestive tract (Fig. 7A). Anterior salivary glands extend along approximately 20% of buccal mass from posterior margin on dorsal surface. Posterior salivary glands large (slightly longer than buccal mass, approximately 80% of digestive gland length). Crop diverticulum present, small. Stomach bipartite. Caecum coiled in single whorl, with striations. Digestive gland approximately ovoid. Muscular intestine reflexed approximately one third along length from proximal end. Ink sac well developed, embedded in ventral surface of digestive gland. Anal flaps present. Upper beak with slightly hooked rostrum and small hood (Fig. 7B). Lower beak with rounded rostrum, hood narrow, widely spread wings and nearly parallel lateral walls (Fig. 7C-D). Radula with 7 teeth and 2 marginal plates in each transverse row (Fig. 10G-H).

FIG. 9, Type material. A, *Octopus harpedon* sp. nov. (♂ holotype, AM C30411) dorsal view; 1-4; arms numbered from dorsal to ventral pair (scale bar = 50mm). B, *Octopus harpedon* sp. nov. (♀ holotype, AM C30412) dorsal view; 1-4: as in A (scale bar = 50mm). C, *Octopus bulbus* sp. nov. (♂ holotype, MV F87067), dorso-lateral view; lr = lateral mantle ridge (scale bar = 20mm). D, *Octopus micros* sp. nov. (♂ holotype, MV F87070) dorsal view (scale bar = 10mm).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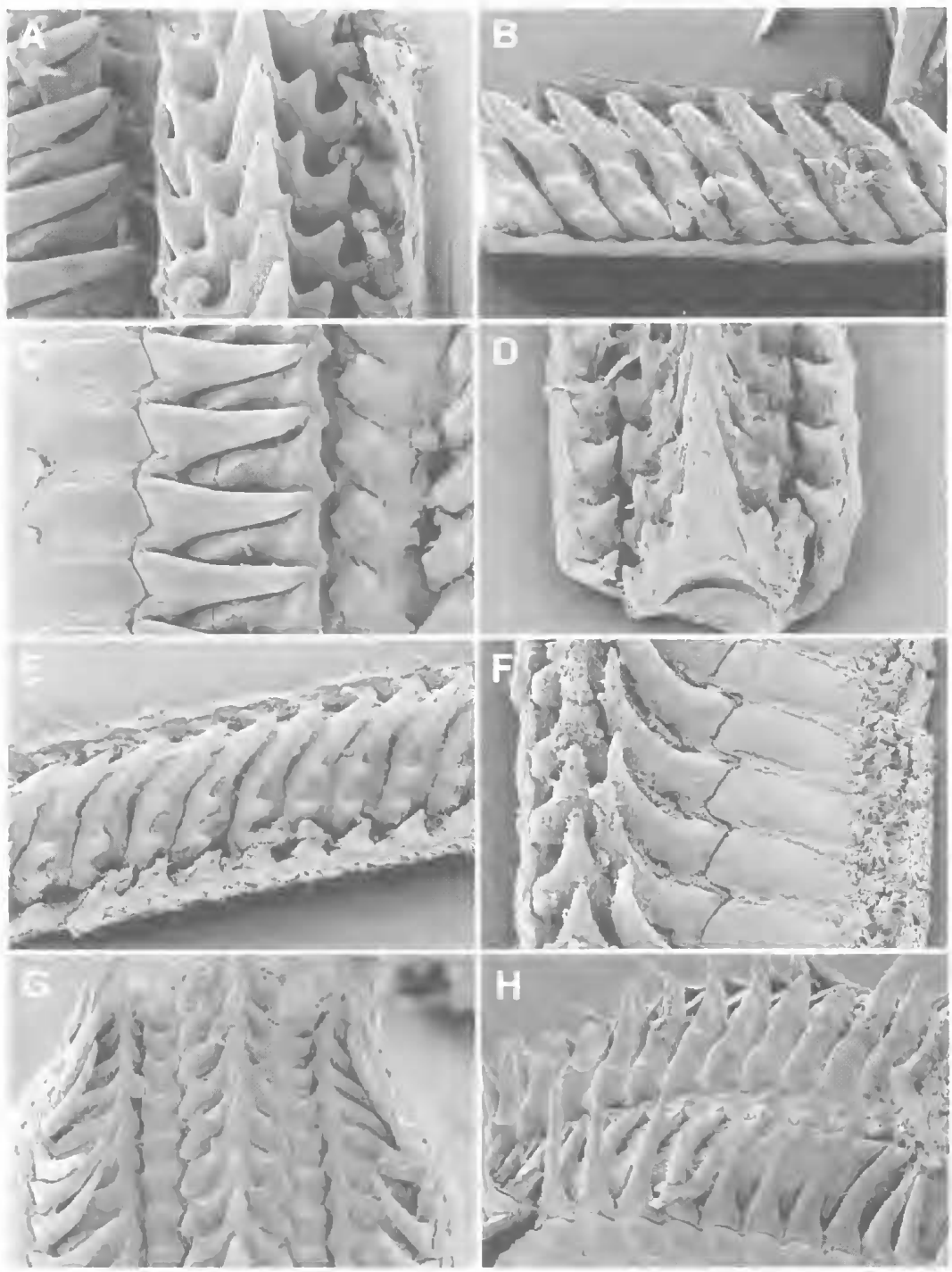

FIG. 10. Radulae. A-C, *Octopus harpedon* sp. nov. radula (♀ paratype, AM C304112). A, dorsal view showing multicuspid rhachidian tooth; B, lateral view showing serial progression of cusps on rhachidian tooth; C, lateral teeth and marginal plates. D-F, *Octopus bulbus* sp. nov. radula (♀ paratype, MV F87069); D, dorsal view showing multicuspid rhachidian tooth; E, lateral view showing serial progression of cusps on rhachidian tooth; F, lateral teeth and marginal plates. G-H, *Octopus micros* sp. nov. radula (♀ paratype, MV F78815); G, dorsal view; H, lateral view.

Rhachidian tooth with 1-2 lateral cusps, typically 1, on each side of short robust medial cone (Fig. 10G). Lateral cusps in asymmetrical seriation, migrating from lateral to medial position over 4-5 transverse rows (Fig. 10H). First lateral teeth unicuspidate with cusp towards lateral edge. Second lateral teeth unicuspidate and long with curved base. Lateral marginal teeth long and straight. Marginal plates square, plain (Fig. 10H).

Male genitalia (Fig. 8A). Terminal organ ('penis') in mature ♂♂ short and robust with simple swollen diverticulum. Spermatophores (Fig. 8B) approximately equal in length with mantle length (20.1, 22.8mm, 97.1, 121.3% ML), and of moderate width (0.5mm [n=2], 2.3, 2.5 % of spermatophore length), produced in low numbers (2, 4 in spermatophore storage sac). Ejaculatory apparatus linear with slight coils at oral end. Oral cap simple, bearing long cap thread. Sperm reservoir 37.3% of total spermatophore length in ♂♂, containing robust sperm cord, most of which forms regular whorls with some bunching to produce a plaited appearance.

Submature ♀ with eggs in undeveloped ovary already large (~2mm) and few in number (<100). This species would produce large eggs and the young are likely to be benthic on hatching.

Colour in life unknown. Preserved specimens red-brown formed by fine uniform chromatophores on dorsal surfaces and lateral arm crown to midline of third arm pair. Darker purple-brown pigmentation around eyes creates a 'bruised' appearance to the eyes (Fig. 6A). Dorsal White Spots (*sensu* Packard & Sanders, 1971) present. Skin relatively soft (preservation artefact?) with a single distinct primary papilla over each eye and 4 papillae in a diamond on the dorsal mantle. Large primary papillae on posterior tip of mantle. Lateral mantle ridge present.

Nothing known of behaviour or general biology. Its depth range (>150m) and small size make it unlikely ever to be observed in the wild.

TAXONOMIC REMARKS. *O. micros* sp. nov. is the first pygmy species reported with a lateral mantle ridge. Two other larger species in the area also possess this ridge, *O. bulbus* described here and *O. australis* Stranks & Norman, 1993. *Octopus micros* is clearly distinguished from *O. bulbus* by the arm formula (4=3=2>1 versus 1>2>3>4), shorter arms (2.3-2.7 versus 4.9-5.6 × ML), lower gill count (6 versus 7-8) and the presence of 'dorsal white spots' (*sensu* Packard & Sanders, 1971) and the diamond of primary papillae on the dorsal mantle (latter two attributes absent in *O. bulbus*).

O. micros is distinguished from *O. australis* by a higher sucker count on the hectocotylised arm (85-93 versus 62-77), shorter arms (2.3-2.7 versus 2.7-4.3 × ML) and a lower gill count (6 versus 7-9). These 2 species share several characters, namely a lateral mantle ridge, similar arm formulae, 'dorsal white spots' and a diamond of primary papillae on the dorsal mantle. These species may share common ancestry.

Only 2 pygmy species have been reported from Australian waters: *O. warringa* Stranks, 1990 and *O. superciliosus* Quoy & Gaimard, 1832 (see Stranks, 1988a). Both are restricted to temperate southern Australian waters. They are easily distinguished from *O. micros* in that they both lack a lateral mantle ridge.

DISCUSSION

Due to the nature of certain marine habitats, our only knowledge of some sea creatures comes from dead material collected by fishing or research trawls. For such animals our capacity to interpret their lives is restricted to deductions based on morphology, stomach contents and habitat associations. The new species described here are all from environments where direct observation is difficult or impossible due to poor water clarity or excessive depths. Combined with the cryptic and/or nocturnal behaviour typical of octopuses, it is likely that none of these species will be observed in their natural environs. Attributes of their morphology, however, may provide some clues to their lifestyles.

O. harpedon is a long-armed species from shallow coastal waters typically clouded with suspended silt over soft sediment substrates. This area is also the regular haunt of abundant tiger sharks and crocodiles, effectively deterring any attempt to find and observe this species *in situ*.

The long arms of *O. harpedon* are similar in scale to those of *Ameloctopus litoralis* Norman, 1992, a small intertidal mudflat species found across northern Australia. *Ameloctopus litoralis* lacks significant webs between the arms and feeds by probing its long and thin arms individually down holes and burrows to capture small crustaceans and fish (Norman, 1992). The long arms and shallow webs of *O. harpedon* suggest that it is similarly using long arms to probe subterranean burrows for crustacean and fish prey. The absence of complex colour patterns

TABLE 1. Counts and measurements (mm) for *O. harpedon, O. bulbus* and *O. micros* spp. nov. d = damaged; fr = frozen distorted specimen; H = hectocotylised arm; InD = indistinct; t = very tip of arm damaged; TO = terminal organ; A-E = web sectors from dorsal sector.

Species	*O. harpedon*	*O. harpedon*	*O. bulbus*	*O. bulbus*	*O. bulbus*	*O. micros*	*O. micros*	*O. micros*
Museum	AMS	AMS	MV	MV	MV	MV	MV	MV
Reg. No.	C304111	C304112	F87067	F87068	F87069	F87070	F78815	F78815
Status	Holotype	Paratype	Holotype	Paratype	Paratype	Holotype	Paratype	Paratype
Sex	Male	Female	Male	Male	Female	Male	Male	Female
Maturity	submature	submature	mature	mature	submature	mature	mature	submature
Mantle length	56.9	96.1	41.1	53.0	49.2	18.8	20.7	24.5
Total length	394	997	251	318	67	67	71	91
Weight (g)	45.3	104.3	27.5	47.2	30.1	4.5	4.0	5.8
Mantle width	20.0	23.9	22.0	23d	22d	14.3	13.1	15.5
Head width	15.0	15.2	21.9	17d	22d	14.3	12.3	13.8
Funnel length	29.3	46.0	20.9	33.0	24.3	6.2	8.5	9.6
Free funnel length	7.0	15.4	6.7	13.0	13.6	3.7	3.8	6.1
Funnel organ limb (medial)	InD	InD	12.5	InD	InD	4.2	InD	5.8
Funnel organ limb (lateral)	InD	InD	10.8	InD	InD	3.9	InD	6.1
Shallowest web depth	A: 10	E: 15	E: 18	E: 26	A: 19fr	A: 10	A: 10	A: 10
Deepest web depth	BCE: 13	C: 21	BC: 23	B: 34	D: 30fr	CD: 13	C: 13	C: 14.5
Arm lengths (L/R): 1	246d 292	543t 591	200 d	d d	275 239d	37 41	39t 43	55 d
2	290d? 334	d 877	171 167	243t 262	233 253	48 50	45 49	d d
3	221 45H	628 495d	106d 82H	240 135H	176 199	39t 42H	48 41H	d d
4	143 148	298t 308t	125 144	187 173	159 d	47 48	47 48	60t 65
Arm width	6.1	5.7	5.7	fr	fr	3.7	3.5	4.5
Sucker diameter	4.0	4.8	3.0	5.2	3.3	2.2	2.3	2.4
Sucker count: R3	49H	d	91H	94H	fr	93H	85H	d
L3	272	291	196 (R4)	fr	fr	156 (R4)	143	153 (R4)
Gill lamellae count: R	10-10	11-10	7-7	8-8	8-8	6-6	6-6	6-7
L	10-10	10-11	7-7	8-8	8-8	6-6	6-6	6-7
Ligula length	3.3	-	6.6	11.6	-	2.7	3.6	-
Calamus length	1.8	-	1.2	2.0	-	1.2	1.3	-
Spermatophore number	-	-	1 (+ 1 in TO)	InD	-	3 (+1 in TO)	2	-
Spermatophore length	-	-	22	InD	-	23	20	-
Spermatophore width	-	-	1.1	InD	-	0.6	0.5	-
Sperm reservoir length	-	-	12	InD	-	8.5	7.5	-
Egg number	-	<100	-	-	<100	-	-	<100
Egg length	-	large	-	-	large	-	-	large
Egg width	-	-	-	-	-	-	-	-

and skin sculpture suggest that this species may be nocturnally active.

The other 2 species described here both possess a lateral mantle ridge. This skin structure is only known in a handful of other described octopods, namely the Australian shallow water *O. australis* Hoyle, 1885 and *O. berrima* Stranks & Norman, 1993, and the deeper water *Benthoctopus leioderma* (Berry, 1911), *Eledone palari* Lu &

Stranks, 1992, *Megaleledone senoi* Taki, 1961 and members of *Bathypolypus* Grimpe, 1921, *Pareledone* Robson, 1932, *Scaeurgus* Troschel, 1857 and *Tetracheledone* Voss, 1955. A partial or broken lateral mantle ridge also occurs in two other shallow water species: *O. hunurong* of the '*Octopus macropus* group' (Norman, 1993a) and *O. fungsiao* of the '*Octopus aegina* group' (Norman, 1993b). Presence of this skin ridge in such disparate taxa suggests either independent origins for this structure or that it is a common primitive state lost in many groups. All the species listed are primarily associated with soft sediment substrates and it is possible that this ridge may relate to their capacity to bury in sand or mud.

Octopus micros is only known from the continental shelf off southern Queensland. This species shows some similarities with *O. australis* and *O. berrima*, from eastern and southern Australia, respectively. All 3 species are unlike any other known shallow-water species and they may represent older Palaeo-austral lineages, the product of the long and isolated northward drift of the Australian continent following the break up of Gondwana around 200 million years ago.

The small size at maturity of *O. micros* is similar to that found in other pygmy species. Such dwarfism appears linked with specialised microhabitats. *O. micropyrsus* Berry, 1953 of California (Lang, 1997) and a species from Tasmania (unpubl. data) occur primarily in kelp holdfasts (*Macrocystis* spp.), while *O. bocki* Adam, 1941 of the tropical Indo-West Pacific lives in coral heads (pers. obs.). Juveniles of many octopus species seek refuge in such porous structures (pers. obs.). It is possible that selective pressures against outgrowing the protection of such micro-refuges (and their resident prey species) may have lead to neotenous dwarfism in certain groups. The small size of *O. micros* may reflect a similar specialization for particular microhabitats.

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